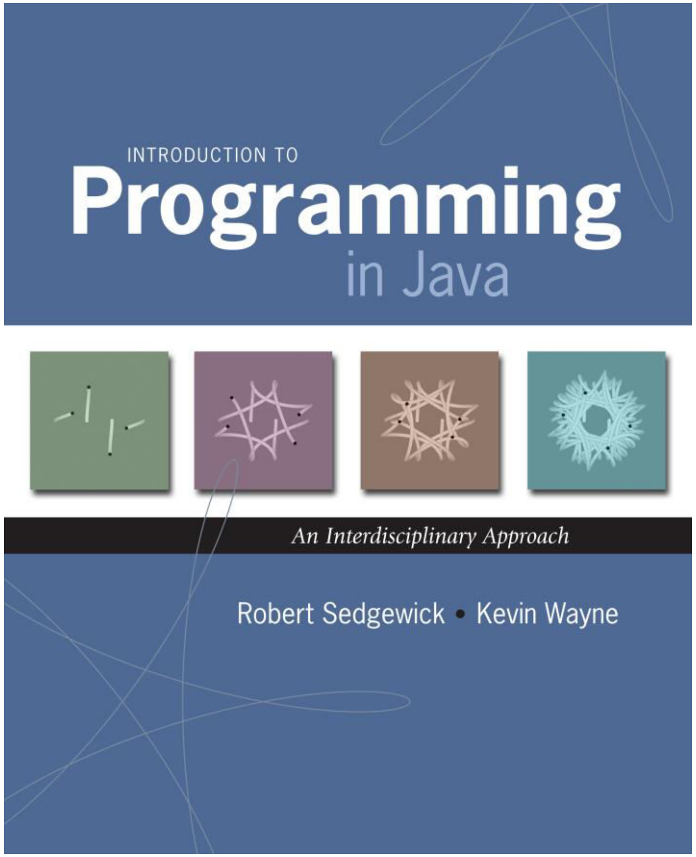
3.1 Objects

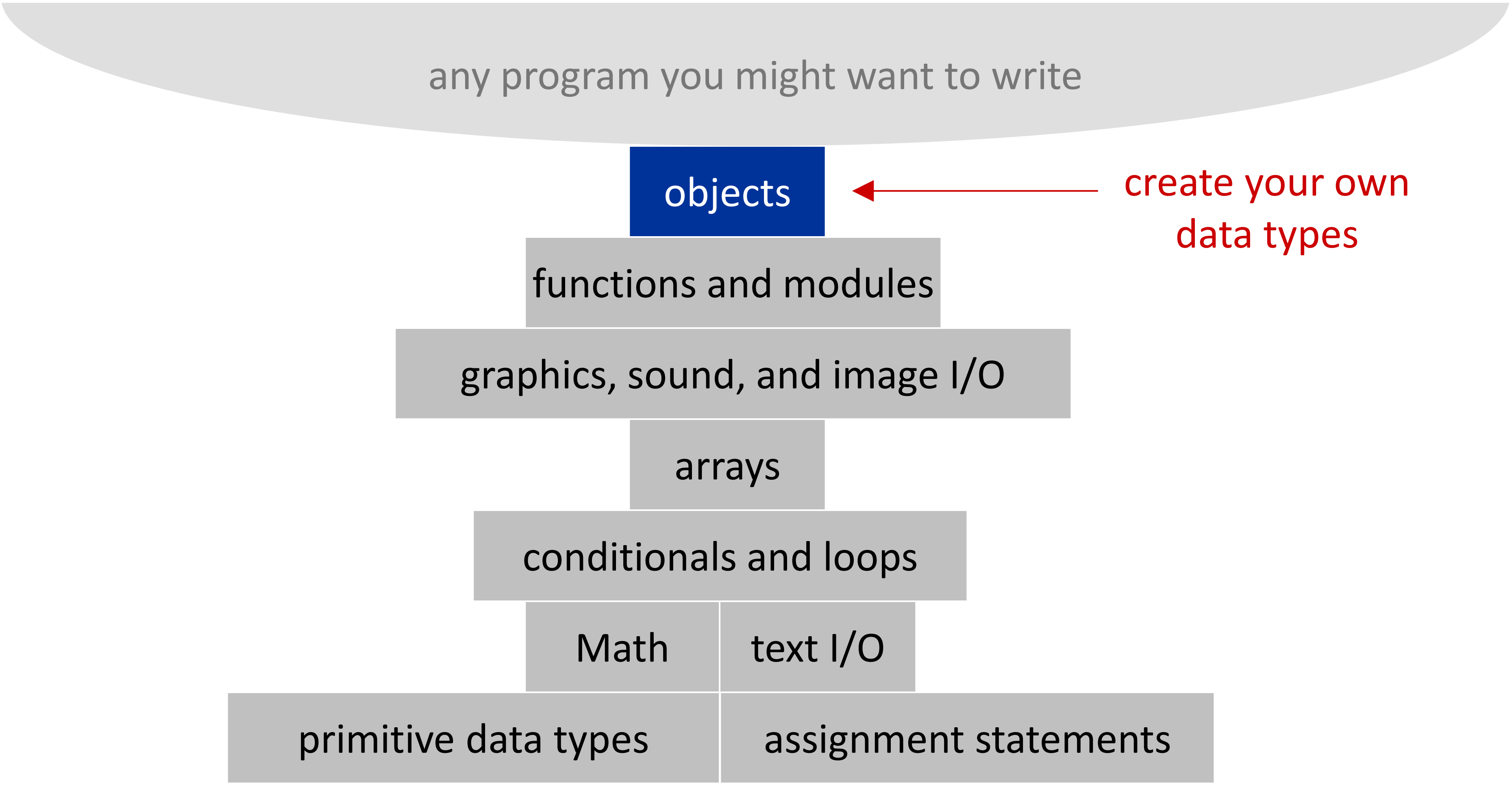


INTRODUCTION TO
Programming
in Java

An Interdisciplinary Approach

Robert Sedgewick • Kevin Wayne

A Foundation for Programming



any program you might want to write

objects

create your own data types

functions and modules

graphics, sound, and image I/O

arrays

conditionals and loops

Math

text I/O

primitive data types

assignment statements

Data Types

Data Types: set of values and associated operations

Primitive Types:

- values map directly to the machine representation
- ops map directly to machine instructions

Data Type	Set of Values	Operations
boolean	**true, false**	not, and, or, xor
int	**-2^{31} to $2^{31}-1$**	add, subtract, multiply
double	any of 2^{64} possible reals	add, subtract, multiply

We want to write programs that handle other data types

- colors, pictures, strings, input streams, …
- complex numbers, vectors, matrices, polynomials, …
- points, polygons, charged particles, celestial bodies, …

Objects

Objects: represent values and operations for more complex data types

- Object variables are called fields
- Object operations are called methods

Data Type	Set of Values	Operations
`Color`	24 bits	get red component, brighten
`Picture`	2D array of colors	get/set color of pixel (i, j)
`String`	sequence of characters	length, substring, compare

Objects are said to encapsulate (hide) its detail

- How an object is implemented is not important
- What it does is important

Objects can be created and referenced with variables

Object-Oriented Programming

Programming paradigm that views a program as a collection of interacting objects

- In contrast, the conventional model views the program as a list of tasks (subroutines or functions)

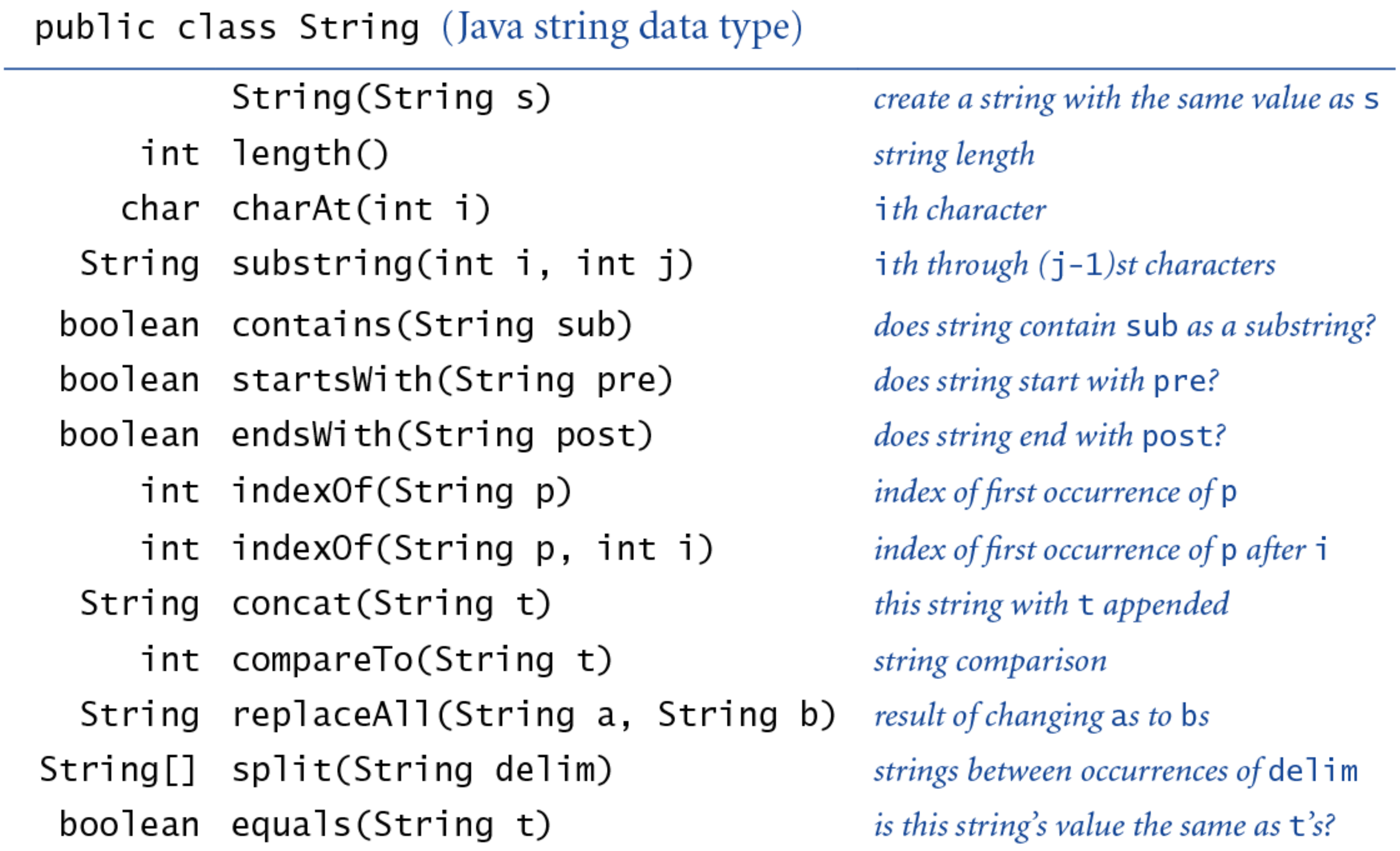
We'll talk about how to:

- Create your own data types (set of values and operations)
- Use objects in your programs (e.g., manipulate objects)

Why would I want to use objects in my programs?

- Simplify your code
- Make your code easier to modify
- *Share an object with a friend*

The String Object



`public class String` (Java string data type)

	`String(String s)`	*create a string with the same value as* `s`
`int`	`length()`	*string length*
`char`	`charAt(int i)`	`i`*th character*
`String`	`substring(int i, int j)`	`i`*th through* (`j-1`)*st characters*
`boolean`	`contains(String sub)`	*does string contain* `sub` *as a substring?*
`boolean`	`startsWith(String pre)`	*does string start with* `pre`*?*
`boolean`	`endsWith(String post)`	*does string end with* `post`*?*
`int`	`indexOf(String p)`	*index of first occurrence of* `p`
`int`	`indexOf(String p, int i)`	*index of first occurrence of* `p` *after* `i`
`String`	`concat(String t)`	*this string with* `t` *appended*
`int`	`compareTo(String t)`	*string comparison*
`String`	`replaceAll(String a, String b)`	*result of changing* `a`*s to* `b`*s*
`String[]`	`split(String delim)`	*strings between occurrences of* `delim`
`boolean`	`equals(String t)`	*is this string's value the same as* `t`*'s?*

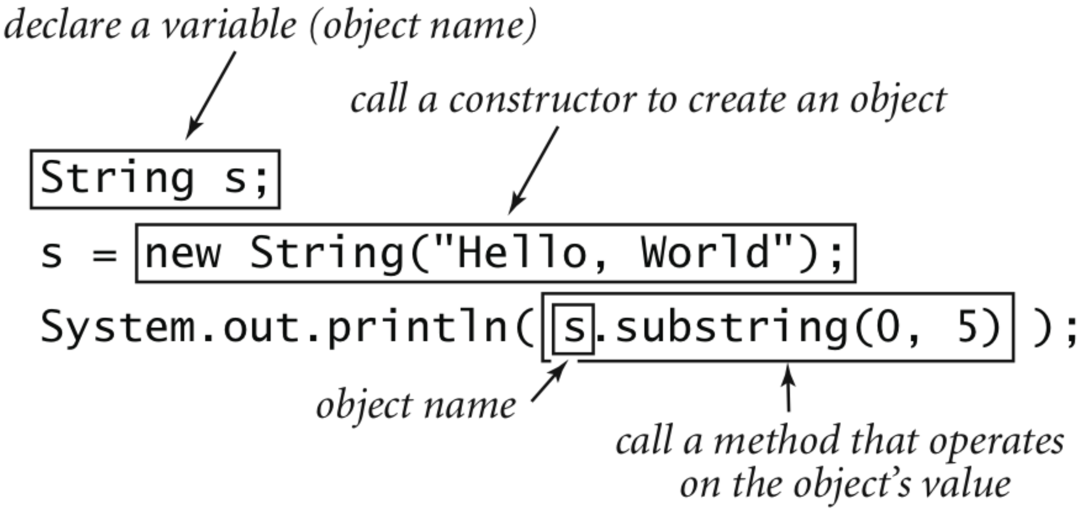
Constructors and Methods

To construct a new object:

- Use keyword `new` (to invoke constructor)
- Use name of data type (to specify which type of object) with associated parameters for the constructor

To apply an operation:

- Use name of object (to specify which object)
- Use the dot operator (to access a member of the object)
- Use the name of the method (to specify which operation)



```
String s;
s = new String("Hello, World");
System.out.println( s.substring(0, 5) );
```

declare a variable (object name)
call a constructor to create an object
object name
call a method that operates on the object's value

Defining Your Own Objects with Classes

- Classes are blueprints or prototypes for new objects

- Classes define all field and method declarations

  … which are repeated for each new object created

- Using a class to create a new object is called *instantiating* an object

  … creating a new object instance of the class

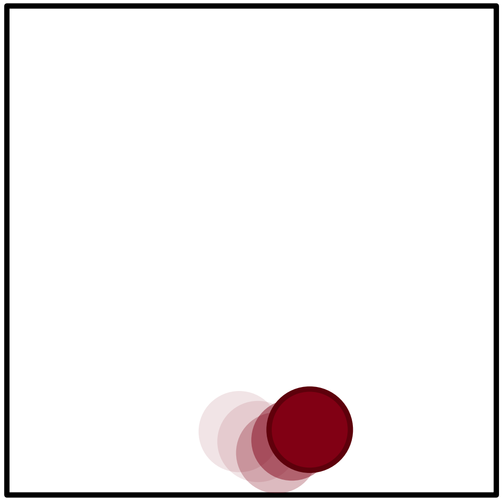
- Classes often model real-world items

Bouncing Ball Object

- What do we want to have the ball do?

  (i.e., what methods should it have?)

- What initial parameters should we specify in the constructor?



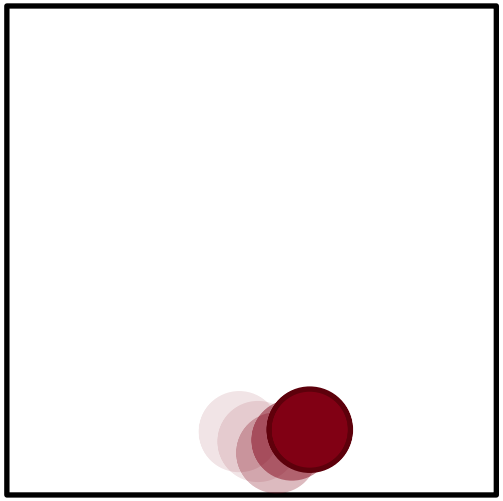
Bouncing Ball Object

- What do we want to have the ball <u>do</u>?

  (i.e., what <u>methods</u> should it have?)

  – void draw() : “Ball, draw thyself!”

  – void update() : simulate the ball’s motion



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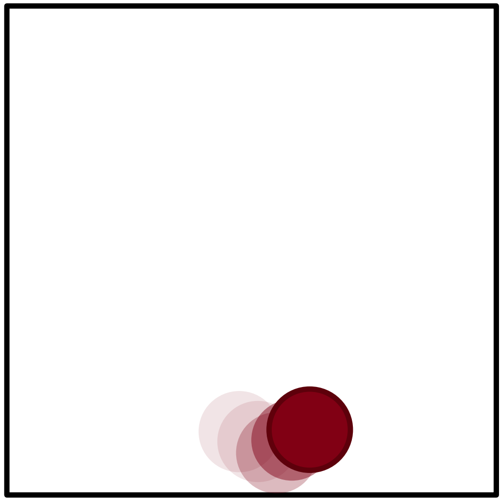


- What initial parameters should we specify in the constructor
  - Ball (int x, int y) : creates a ball at (x, y)

These methods constitute the ball’s API

Bouncing Ball Object

Given only the API, we can use the object in a program:

```
static Ball[] balls = new Ball[20];

public static void setup() {
  // Create all new Ball objects
  for (int i = 0; i < balls.length; i++) {
    balls[i] = new Ball(Math.random(),
                        Math.random());
  }
}

public static void draw() {
  StdDraw.clear(StdDraw.WHITE);

  for (int i = 0; i < balls.length; i++) {
    balls[i].update();
    balls[i].draw();
  }
}
```

Declare an array of Balls.

```
Ball
-------------------
Ball(int x, int y)
void draw()
void update()
```

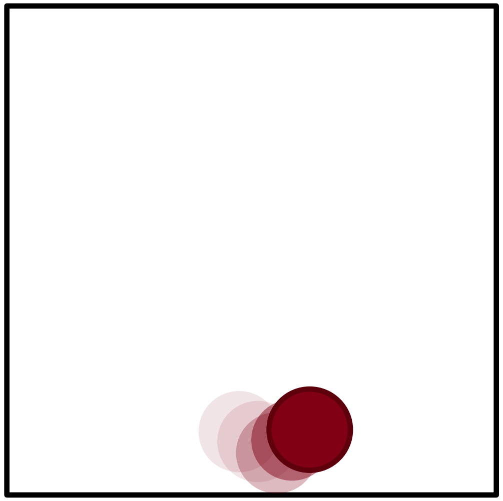
New objects are created with the ***new*** keyword.

Methods of objects stored in the array are accessed using dot-notation.

Bouncing Ball Object Implementation

- What fields should the ball have?

  (i.e., what does it need to know about itself?)
  - position (x,y)
  - velocity (dx, dy)
  - acceleration due to gravity (ay)
  - size, color, etc...



- The class Ball is implemented in the same file (BouncingBallObjectDemo.java)

Defining Your Own Objects with Classes

```
// Defining a new object
public class MyObjectName {

  // All field variable declarations go here.
  // Field variables should be private.

  /* Define a special function-like statement called
   * the object's constructor.
   * Its name is same as the class name,
   * with no return value.
   */
  public MyObjectName( optional arguments ) {
    // Perform all initialization here
  }

  // Declare all method functions here

}
```

```java
// A Ball Class
public class Ball {

  // Fields
  private double ay = 0.002;   // y acceleration (gravity)
  private double x;            // x position
  private double y;            // y position
  private double dx;           // x velocity
  private double dy;           // y velocity
  private double radius = 0.05;

  // Constructor
  public Ball() {
    x = StdRandom.uniform(radius, 1 - radius);
    y = StdRandom.uniform(0.5, 1);
    dx = StdRandom.uniform(-0.03, 0.03);
    dy = StdRandom.uniform(0.0, 0.05);
  }

  ...
}
```

```
private boolean canBounceOffWalls = true;
private boolean canBounceOffFloors = true;

// Methods
public void update() {
  // Move ball
  x += dx;
  y -= dy;
  dy += ay;


  // Bounce off walls and floor
  if (canBounceOffWalls && (x < radius || x > (1 - radius))) {
      dx = -dx;
      canBounceOffWalls = false;
  }
  if (canBounceOffFloors && y < radius) {
      dy = -0.9*dy;
      canBounceOffFloors = false;
  }

  // reset ready-to-bounce flags
  if (x >= radius && x <= (1 - radius))   canBounceOffWalls = true;
  if (y >= radius)    canBounceOffFloors = true;
}

public void draw() {
  PennDraw.filledCircle(x, y, radius);
}
```

Comparing Declarations and Initializers

```
int      i;
int      j  = 3;
float    f  = 0.1;
float[]  f2 = new float[20];
String   s1 = "abc";
String   s2 = new String("abc");
Ball     b  = new Ball();

Ball[]   b2 = new Ball[20];
for (int i = 0; i < b2.length; i++) {
    b2[i] = new Ball();
}
```

Object References

- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

addr	value
C0	0
C1	0
C2	0
C3	0
C4	0
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

main memory
(64-bit machine)

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```
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b1.update();
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Ball b2 = new Ball();
b2.update();

b2 = b1;
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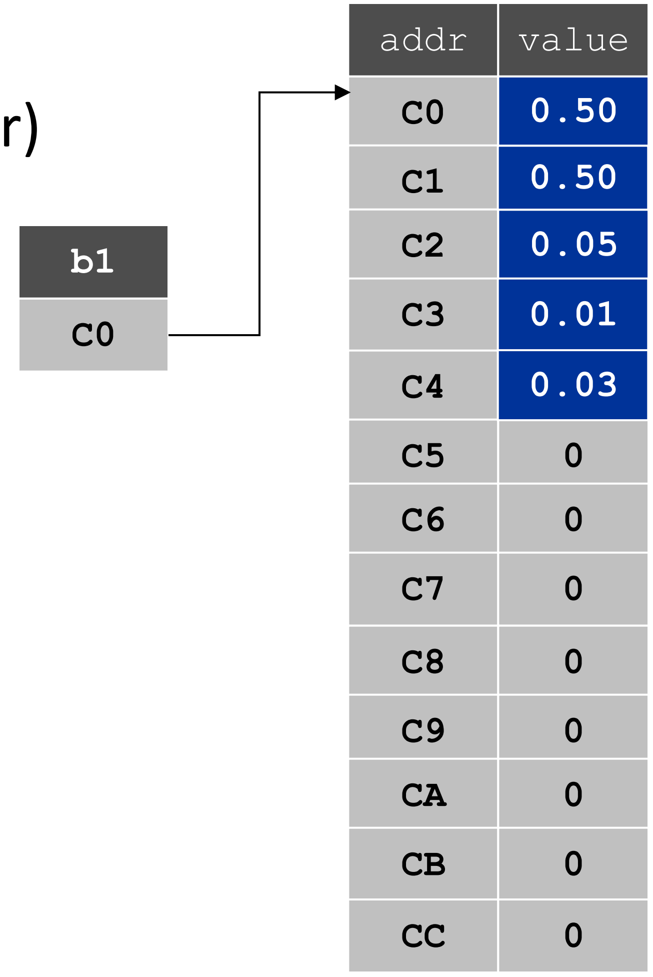

b1
C0

addr	value
C0	0.50
C1	0.50
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

registers

main memory
(64-bit machine)

Object References

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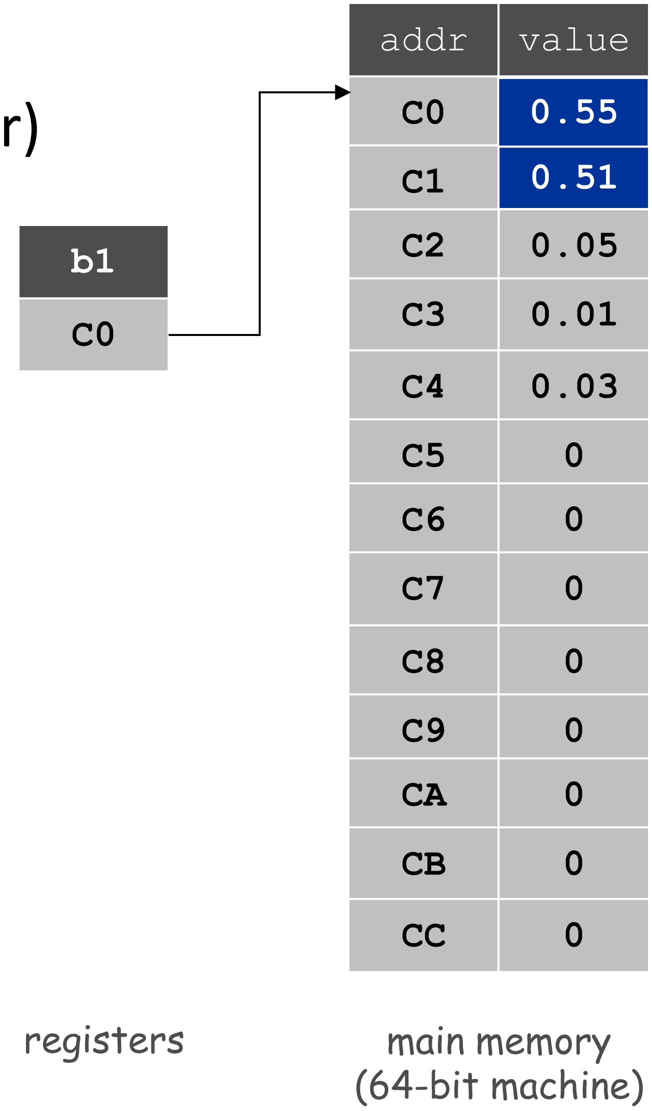
```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```



b1
C0

addr	value
C0	0.55
C1	0.51
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

registers

main memory (64-bit machine)

Object References

- Allow client to manipulate an object as a single entity
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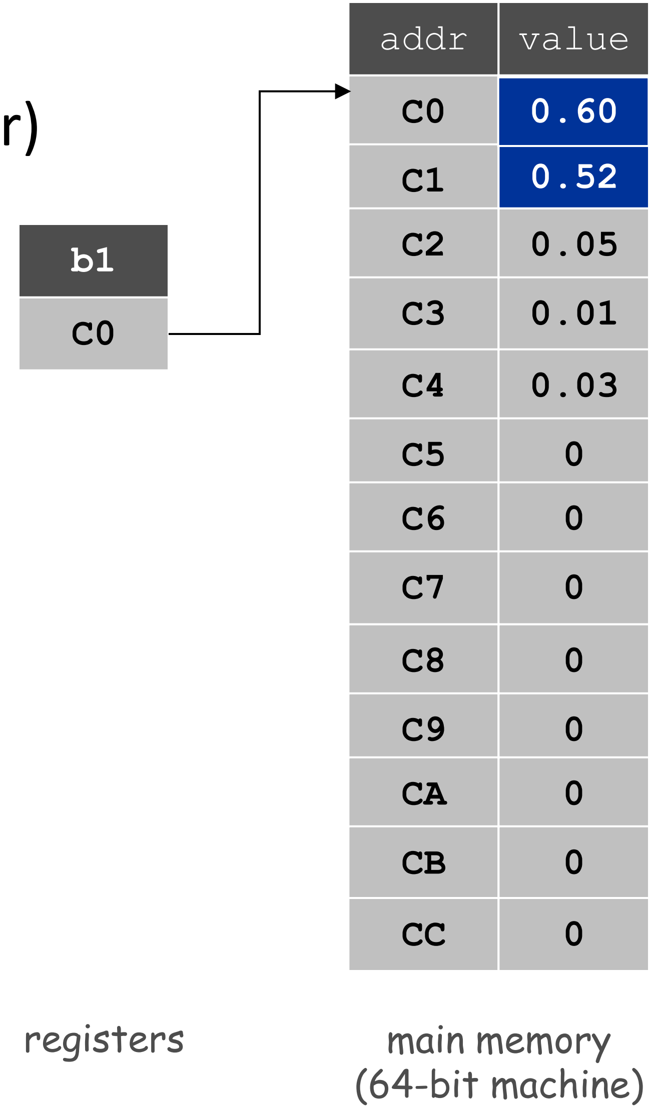
```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```



b1
C0

addr	value
C0	0.60
C1	0.52
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

registers

main memory
(64-bit machine)

Object References

- Allow client to manipulate an object as a single entity
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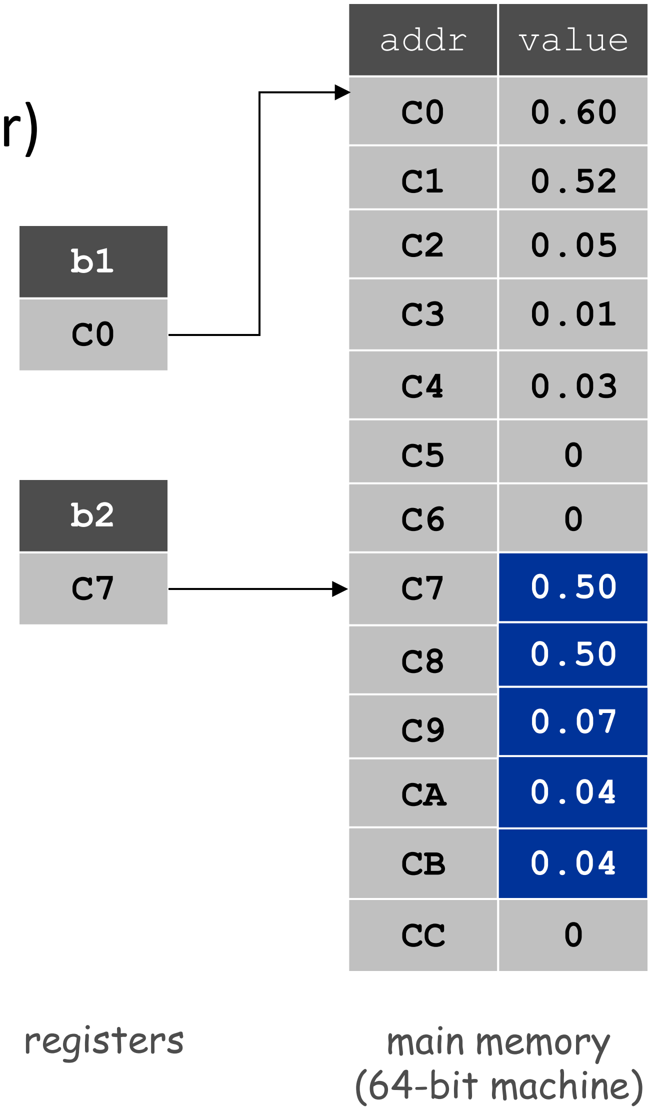
```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```



b1
C0

b2
C7

registers

addr	value
C0	0.60
C1	0.52
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0.50
C8	0.50
C9	0.07
CA	0.04
CB	0.04
CC	0

main memory
(64-bit machine)

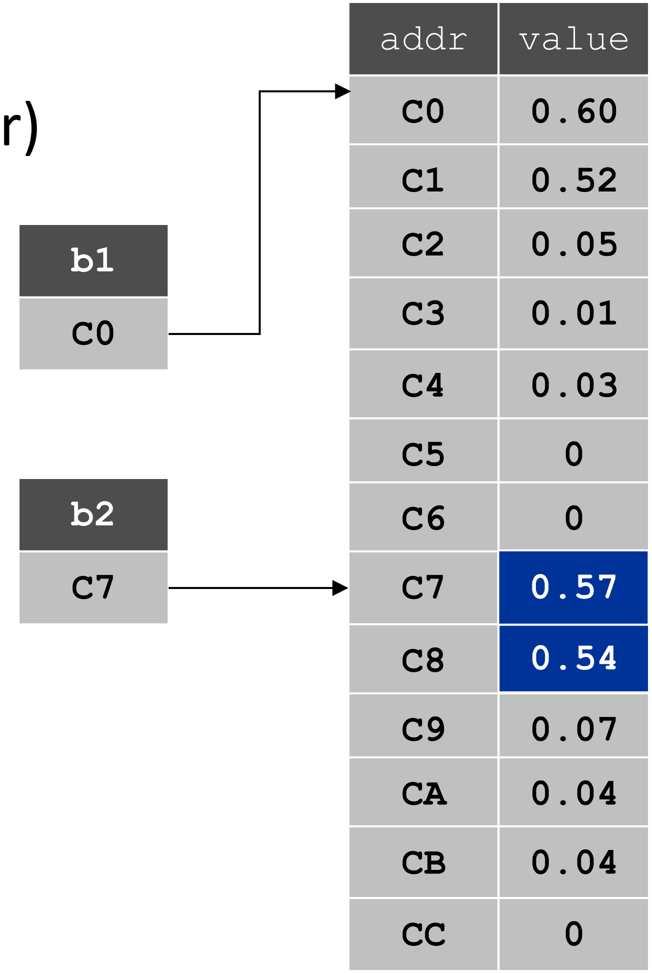
Object References

- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```



b1
C0

b2
C7

addr	value
C0	0.60
C1	0.52
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0.57
C8	0.54
C9	0.07
CA	0.04
CB	0.04
CC	0

registers

main memory
(64-bit machine)

Object References

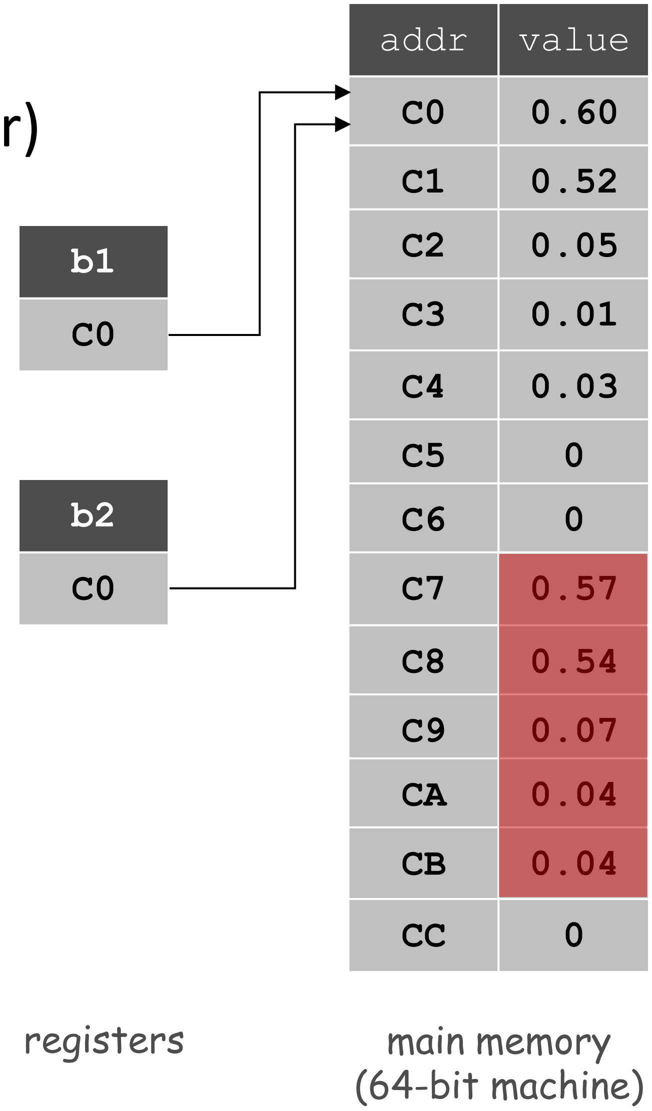
- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

C7 - CB can be reused for other variables. Known as garbage collection in java.



b1
C0

b2
C0

addr	value
C0	0.60
C1	0.52
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0.57
C8	0.54
C9	0.07
CA	0.04
CB	0.04
CC	0

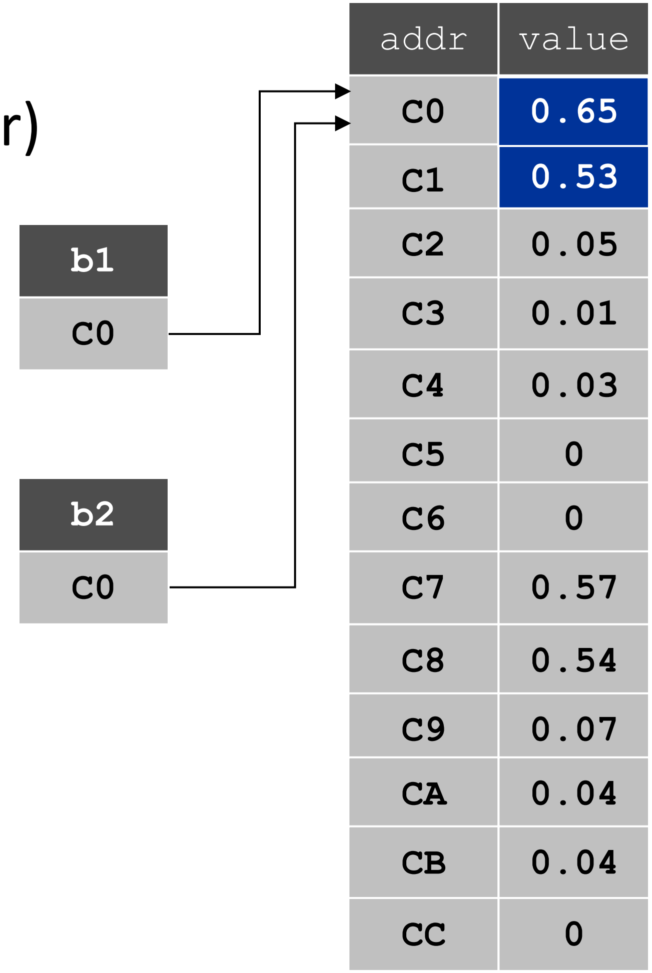
Object References

- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```



b1
C0

b2
C0

addr	value
C0	0.65
C1	0.53
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0.57
C8	0.54
C9	0.07
CA	0.04
CB	0.04
CC	0

registers

main memory
(64-bit machine)

Moving `b2` also moves `b1` since they are aliases that reference the same object.

Pass-By-Value

Arguments to methods are always passed by value.

- Primitive types: passes copy of value of actual parameter.
- Objects: passes copy of reference to actual parameter.

```
public class PassByValue {
   static void update(int a, int[] b, String c) {
      a    = 7;
      b[3] = 7;
      c    = "seven";
      System.out.println(a + " " + b[3] + " " + c);
   }
   public static void main(String[] args) {
      int a = 3;
      int[] b = { 0, 1, 2, 3, 4, 5 };
      String c = "three";
      System.out.println(a + " " + b[3] + " " + c);
      update(a, b, c);
      System.out.println(a + " " + b[3] + " " + c);
   }
}
```

Encapsulation

Access Control

- Encapsulation is implemented using ***access control***.
  - Separates interface from implementation
  - Provides a boundary for the client programmer
- Visible parts of the class (the ***interface***)
  - can be used and/or changed by the client programmer.
- Hidden parts of the class (the ***implementation***)
  - Can be changed by the class creator without impacting any of the client programmer’s code
  - Can’t be corrupted by the client programmer

Access Control in Java

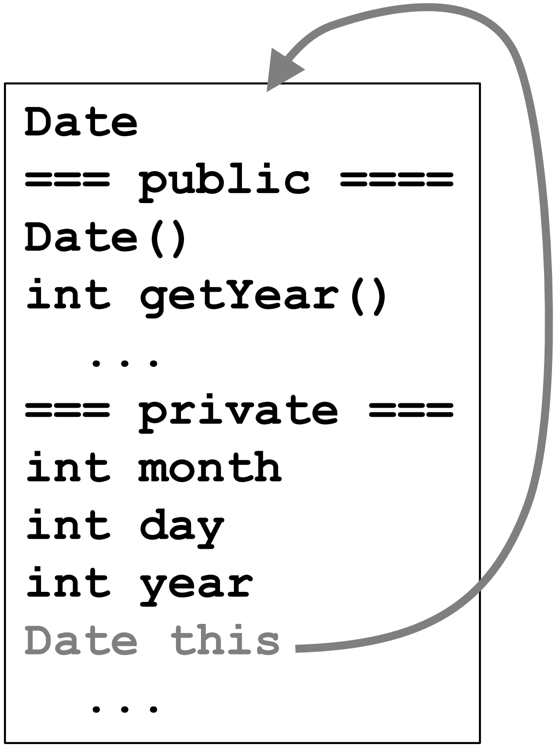
- ***Visibility modifiers*** provide access control to instance variables and methods.
  - ***public*** visibility - accessible by everyone, in particular the client programmer
    - A class' interface is defined by its public methods.
  - ***private*** visibility - accessible only by the methods within the class
  - Two others—***protected*** and **package**—later

Good Programming Practice

- Combine methods and data in a single class
- Label all instance variables as **private** for information hiding
  - The class has complete control over how/when/if the instance variables are changed
  - Fields primarily support class behavior
- Minimize the class' public interface

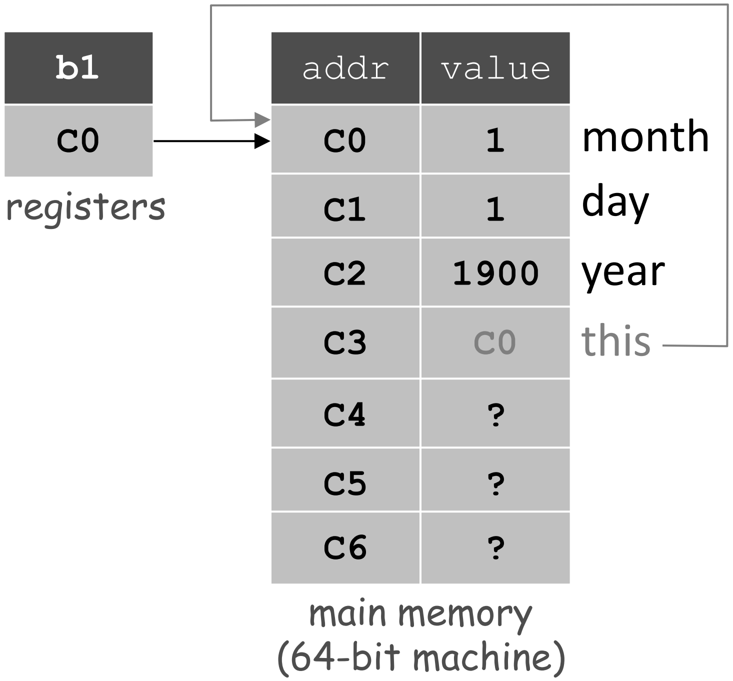
Using **this**

You can think of `this` as an implicit private reference to the current instance.



```
Date
=== public ====
Date()
int getYear()
   ...
=== private ===
int month
int day
int year
Date this
   ...
```

```
Date b1 = new Date();
```



b1
C0

registers

addr	value	
C0	1	month
C1	1	day
C2	1900	year
C3	C0	this
C4	?	
C5	?	
C6	?	

main memory
(64-bit machine)

Note that **`b1.year`** and **`b1.this.year`** refer to the same field

Overloaded Constructors

```
public class Date {
   private int month;      // 1 - 12
   private int day;        // 1 - 31
   private int year;       // 4 digits

   // no-argument constructor
   public Date() {
     month = 1;
     day = 1;
     year = 1900;
   }

   // alternative constructor
   public Date(int month, int day, int year) {
     this.month = month;
     this.day = day;
     this.year = year;
   }

   ...
}
```

```
// 1 Jan 1900
Date d1 = new Date();

// 30 Oct 2013
Date d2 = new Date(10, 30, 2013);
```

Accessors & Mutator

- Class *behavior* may allow access to, or modification of, individual private instance variables.

- Accessor method
  - retrieves the value of a private instance variable
  - conventional to start the method name with **`get`**
- Mutator method
  - changes the value of a private instance variable
  - conventional to start the name of the method with **`set`**

- Gives the client program indirect access to the instance variables.

More Accessors and Mutators

Question: Doesn’t the use of accessors and mutators defeat the purpose of making the instance variables `private`?

Answer: **No**

- The class implementer decides which instance variables will have accessors.
- Mutators can:
  - validate the new value of the instance variable, and
  - decide whether or not to actually make the requested change.

Accessor and Mutator Example

```
public class Date {
   private int month;    // 1 - 12
   private int day;      // 1 - 31
   private int year;     // 4-digit year

   // accessors return the value of private data
   public int getMonth()  { return month; }

   // mutators can validate the new value
   public boolean setMonth(int month) {
    if (1 <= month && month <= 12) {
        this.month = month;
        return true;
    }
    else // this is an invalid month
       return false;
   }
   }
   // rest of class definition follows
}
```

Accessor/Mutator Caution

- In general you should NOT provide accessors and mutators for all private instance variables.
  - Recall that the principle of encapsulation is best served with a *limited class interface*.

Private Methods

- Methods may be private.
  - Cannot be invoked by a client program
  - Can only be called by other methods within the same class definition
  - Most commonly used as “helper” methods to support top-down implementation of a public method

Private Method Example

```
public class Date {
   private int month;   // 1 - 12
   private int day; // 1 - 31
   private int year;    // 4-digit year

   // accessors return the value of private data
   public int getMonth()  { return month; }

   // mutators can validate the new value
   public boolean setMonth(int month) {
    if (isValidMonth(month)) {
        this.month = month;
        return true;
    }
    else // this is an invalid month
       return false;
   }

   // helper method - internal use only
   private boolean isValidMonth(int month) {
     return 1 <= month && month <= 12;
   }
}
```

Static and Final

Static Variable

- A ***static variable*** belongs to the class as a whole, not just to one object.

- There is only one copy of a static variable per class.
  - All objects of the class can read and change this static variable.

- A static variable is declared with the addition of the modifier `static`.

```
static int myStaticVariable = 0;
```

Static Constants

- A ***static constant*** is used to symbolically represent a constant value.
  - The declaration for a static constant includes the modifier **final**, which indicates that its value cannot be changed:

```
public static final float PI = 3.142;
```

- It is not necessary to instantiate an object to access a static variable, constant or method.
- When referring to such a constant outside its class, use the name of its class in place of a calling object.

```
float radius = MyClass.PI * radius * radius;
```

Rules for Static Methods

- Static methods have no calling/host object (they have no **this**).
- Therefore, static methods cannot:
  - Refer to any instance variables of the class
  - Invoke any method that has an implicit or explicit **this** for a calling object
- Static methods may invoke other static methods or refer to static variables and constants.
- A class definition may contain both static methods and non-static methods.

main is a Static Method

Note that the method header for main( ) is

```
public static void main(String[] args)
```

Being static has two effects:

- main can be executed without an object.
- “Helper” methods called by main must also be static.

Any Class Can Have a main( )

- Every class can have a public static method name main( ).
- Java will execute main in whichever class is specified on the command line.

```
    java <className>
```

- A convenient way to write test code for your class.

Static Review

- Given the skeleton class definition below

```
public class C {
  public int a = 0;
  public static int b = 1;

  public void f() {…}
  public static void g() {…}
}
```

- Can body of f() refer to a?
- Can body of f() refer to b?
- Can body of g() refer to a?
- Can body of g() refer to b?
- Can f() call g()?
- Can g() call f()?

For each, explain why or why not.